

INDIRECT ILLUMINATION
WITH NITROGEN - FILLED LAMPS

BY

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Indirect illumination with
nitrogen-filled lamps

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INDIRECT ILLUMINATION
WITH NITROGEN - FILLED LAMPS

A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

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Approved
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PREFACE

In recent years, the development of illuminating engineering and the demand for illuminating engineers has increased rapidly. People in general, have come, at last, to realize that different classes of work require different forms of illumination. One of the latest accomplishments in this branch of engineering has been the development of the gas-filled bulb in connection with the metallic filament, and more particularly the growth of the nitrogen filled lamp. Owing to the fact that it is only recently that the nitrogen-filled lamps have been put on the market, complete sets of data and complete tests have not as yet been made. The lack of data on this form of lamp led the authors to use this as their thesis, with the results obtained and given in the text.

The authors wish to acknowledge their indebtedness to Professors Freeman and Marsh of the Electrical Department of the Armour Institute of Technology for their valuable suggestions

PREFACE

In recent years, the development of illumination engineering and the demand for illumination engineering has increased rapidly. In general, it is believed that different classes of work require different forms of illumination. One of the latest developments in this branch of engineering has been the development of the gas-filled bulb in connection with the metallic filament, and more particularly the growth of the nitrogen-filled lamp. It is only recently that the nitrogen-filled lamp has been put on the market, complete sets of data and complete data have not yet been made. The lack of data on this form of lamp has led the authors to use this as their basis, with the results obtained and given in the text.

The authors wish to acknowledge their indebtedness to Professor Freeman and staff of the Electrical Department of the University of Toronto for their valuable suggestions.

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Co., The Radio-Lux Co., and the City Electric
Co.

May, 1918.

CHAPTER I

Introduction

The study of the physiological requirements for satisfactory illumination has brought to light the shortcomings of the ordinary direct lighting. The harmful effects upon the eyes from the use of artificial exposed light may be divided into three parts. First, the heat effect: Light radiation is a form of energy and upon entering the eye is absorbed and converted into heat. While the power of ordinary illuminants is not sufficient to cause burns, it does cause eye fatigue and serious inflammation. The second harmful effect is due to the strain encountered by the eye when trying to perceive equally well both dark and light objects in a room. The magnitude of the strain on the eye depends upon the position of the light with reference to the eye; but nothing except the removal of the light from the range of vision will relieve the eyes of this strain.

CHAPTER I
Introduction

The study of the physiological conditions for satisfactory illumination has tended to limit the effectiveness of the ordinary lighting. The harmful effects upon the eyes from the use of artificial exposure have been divided into three parts. First, the harmful effect of light radiation is a form of energy and upon entering the eye is absorbed and converted into heat. While the power of ordinary illuminance is not sufficient to cause damage, it does cause eye fatigue and serious inflammation. The second harmful effect is due to the strain encountered by the eye when trying to perceive equally well both day and night objects in a room. The magnitude of the strain on the eye depends upon the position of the light with reference to the eye; but whatever except the removal of the light from the room of vision will relieve the eyes of this strain.

The third harmful effect of exposed lighting is the fatigue due to annoying shadows. If the room is lighted with a single unit, there will be only one deep shadow; but if, as is more often the case, a number of units are distributed throughout the room, the eye is confronted with a multiplicity of light shadows which can not be avoided.

To eliminate these shortcomings of the common methods of illumination, numerous methods have been devised, foremost among which is indirect illumination. The resulting illumination protects the eye from direct heat rays. Since the light source is completely hidden, the pupil of the eye may expand freely, and so easily distinguish all objects equally well. Furthermore, shadows are eliminated to a more marked degree than is possible by any other of the present systems of illumination.

Indirect illumination unfortunately requires scientific planning and designing which is not

The first method of general illumination is the lighting due to artificial sources. The room is lit with a single unit, but it will be only one beam of light; but it is not given the same, a number of units are distributed throughout the room, the eye is not troubled with a multiplicity of light sources which can not be avoided.

To eliminate these shortcomings of the common methods of illumination, numerous systems have been devised, foremost among which is indirect illumination. The resulting illumination comes from the eye from direct light rays. Since the light source is completely hidden, the pupil of the eye is not strained freely, and so nearly identical all objects appear well. Furthermore, shadows are eliminated to a great extent, thus it is possible to get clear of the present systems of illumination. Indirect illumination automatically requires scientific planning and designing which is not

essential for direct lighting. With this object in view, a series of tests were carried out with an Alexlite fixture using a nitrogen filled bulb, to ascertain the most advantageous position of the filament with respect to the ceiling and also the position of the bowl with respect to the ceiling.

newest the first light. The first
object in view, a series of facts were verified
out with an absolute future with a minimum
times only, to ascertain the most advantageous
position of the filament with respect to the
celling and also the position of the foot with
respect to the ceiling.

CHAPTER II

Photometers

In this test, three photometers were used: first, the Lumner-Brodhun photometer; second, the globe photometer and third, the Sharp-Miller photometer.

The Lumner-Brodhun photometer consists of an optical arrangement whereby the two sides of the screen can be viewed at the same time. A diffusing screen, SS' , Fig. I, of high refracting power, is placed with its plane normal to the photometric axis of the bench. The light reflected from the two sides of the screen SS' falls upon the mirrors M_1 and M_2 and is reflected along a normal to the surface of a triangular prism A and B. The observer looking through the telescopic tube O directed normally to B, clearly views a divided field illuminated partly by one source and partly by the other.

The rays from I_1 pass directly through the central part of the prisms illuminating the

Introduction

In this book, three photographs are used: (1) the lower-portion photograph; (2) the upper-portion photograph; and (3) the whole photograph. The lower-portion photograph is the one which is most commonly used.

The lower-portion photograph is taken at an angle of about 45 degrees to the horizontal. The upper-portion photograph is taken at an angle of about 15 degrees to the horizontal. The whole photograph is taken at an angle of about 15 degrees to the horizontal. The lower-portion photograph is the one which is most commonly used.

The upper-portion photograph is the one which is most commonly used. The whole photograph is the one which is most commonly used. The lower-portion photograph is the one which is most commonly used. The upper-portion photograph is the one which is most commonly used. The whole photograph is the one which is most commonly used. The lower-portion photograph is the one which is most commonly used.

The whole photograph is the one which is most commonly used. The lower-portion photograph is the one which is most commonly used. The upper-portion photograph is the one which is most commonly used. The whole photograph is the one which is most commonly used.

central portion of the field. The rays from I_2 pass in the same way into the prism B and constitute the outer portion of the field of view. The paths of the light rays viewed through the eye-piece are indicated by full lines in Figure I. Those shown dotted from I_1 are reflected by the prism B out of the line of vision while those represented by the dotted line from I_2 pass directly through the prisms out of view. With this arrangement one observes a two-part illuminated field as shown at O.

Ulbricht Globe Photometer. One of the simplest and most satisfactory methods of measuring mean spherical intensities is by means of the globe photometer. The determination of the mean spherical candle power of light sources by a single measurement was accomplished by Ulbricht in 1900 after having derived the theorem that any area upon the inner surface of a sphere is illuminated by all other bright patches proportional to their brightness only,

[illegible]

and irrespective of their position.

The globe photometer used was a hollow sphere 120 cm. in diameter. The frame of the globe is made in two hemispheres, being formed of office netting. The interior of the frame is lined with two thin coatings of asbestos, 0.1587 inches thick, one fastened to the netting with small wires and the other placed upon the first and secured to it by a silicon compound. The two hemispheres are rigidly held together by means of metal clamps.

An opening 46.356 cm. in diameter in the upper portion for inserting the lamps and a similar opening near the bottom for repairing the interior surface were provided for. The interior of the sphere was coated with white calcimine. One observation window, covered with a diffusing glass, was provided for, a little below the central horizontal position.

The general theory of the spherical photometer, as given by Dr. Block is as follows.

and temperature of their position.

The glass thermometer used here is of the

surface 100 mm. in diameter. The frame of the

glass is made in two parts, one for the

of other parts. The interior of the frame

is lined with two thin sheets of asbestos,

0.001 inch thick, one fastened to the

ring with small rivets and the other glass

the inner and covered in it by a silver

plate. The two plates are held in

position by means of small clamps.

It is divided into two in diameter in the

upper portion for inserting the lamp and a

small opening near the bottom for passing

the indicator surface and provided for.

Location of the surface was noted with

care. One observation showed, however,

with a different glass, the position of

is the same as the central horizontal position.

The general theory of the physical

which is given in the book is as follows.

When a source of light is placed inside a spherical shell having a matt surface, the light received by any part of the interior surface can be considered in two parts, the direct illumination from the light source, and the reflected illumination.

Assume a surface P (Fig. II) to be illuminated by radiation from a small luminous area dA , the brightness of which is B ; then the light received on a unit area at P is $\frac{B \, dA \, \cos a \, \cos b}{r^2}$, a and b being the angles which r makes with the normals to the two surfaces. Let (Fig. III) represent a section through the photometer into which is inserted for measurement a lamp L, and consider the illumination of the surface at a point P by light reflected from a small area dA , and the circle shown be a section through the point P and the area dA , then the light received on dA from the lamp directly will be $E_A \, dA$, and the $\int E_A \, dA = F$, the total light emitted by the

the system of illumination.

[illegible]

lamp. The intensity of dA is kE_A since the surface is perfectly matt and throws the light in all directions equally, k being the reflecting constant for the surface. The light received from the surface dA at P once reflected is

$$F_A = \frac{k I_A dA \cos^2 a}{r^2} = \frac{k I_A dA}{4r^2}$$

Hence the illumination at P due to once reflected light from the whole surface of the

sphere will be $\frac{k}{4r^2} \int E_A dA = \frac{k}{4r^2} F$.

The illumination at P by light twice reflected will be $\left(\frac{k}{4r^2}\right)^2 F$.

The total illumination at P due to reflected light is $F(k/4r^2 + (k/4r^2)^2 + (k/4r^2)^3 - \dots) = KF$ where K is the constant of the instrument and depends upon the size of the sphere and the quality of the interior surface.

Thus it can be seen that the illumination of the interior of the sphere is theoretically uniform and proportional to the total light emitted by the lamp; therefore if a small area be screened from the direct rays of the lamp,

From the intensity of light at the surface of the sphere, the intensity of light at the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere. The intensity of light at the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere.

$$I = \frac{P}{4\pi r^2} = \frac{P}{4\pi (R + r)^2}$$

From the illumination at the surface of the sphere, the illumination at the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere. The illumination at the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere.

The total illumination at the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere. The total illumination at the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere.

Thus it can be seen that the illumination of the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere. The illumination of the surface of the sphere is proportional to the square of the distance from the surface of the sphere to the surface of the sphere.

the remaining illumination of that area is proportional to the mean spherical candle power of the lamp.

Sharp - Miller Photometer. The Sharp - Millar photometer is the portable photometer most extensively used in this country. In it as embodied the characteristics of an ideal photometer. It has the best method of obtaining a photometric balance; it is portable, simple in operation, and is adaptable as a reliable source of light for a comparison standard. The sensitive photometric device is a modification of the Lumner Brodhun equality of brightness photometer, which is viewed through a collapsible telescopic eye-piece through the side of the box.

The photometrical balance is obtained by looking through the eyepiece and varying the distance between the comparison lamp and the photometric screen. The comparison lamp consists of a tungsten low voltage lamp of the battery type. In circuit with it are placed

The resulting information is then used to
construct the new system model which is
the input.

When - after the system, the model is
constructed in the system's knowledge base
and is used in this way. It is the
model of the system's behavior at any time
which is the best method of obtaining
information. It is possible, since the
operation, and is regarded as a system's
of light for a computer system. The model

the system's model is a modification of
the system's model of behavior which
which is used to obtain a solution
which is used to obtain a solution

The model's behavior is obtained by
looking through the system and seeing the
distance between the computer and the
photoelectric system. The computer has
also a computer for voice input of the
system type. In addition, it is also

an ammeter and a small rheostat for regulating the current. By maintaining the current constant in the standard, the intensity is kept at the proper value.

The light from the comparison lamp falls upon a milk glass plate which is viewed through the eyepiece. The intensity of the light upon this plate is made to vary inversely as the square of the distance from the comparison source by making the inside of the box black and interposing a system of moving black screens which prevent any light from falling upon the plate except that which comes from the comparison source.

The scale upon which the readings are indicated is made of translucent celluloid and is illuminated by means of a small slit in the housing of the comparison lamp so that it may be read in dark places without the aid of other light. The scale is graduated with an inverse-square scale and is placed over a longitudinal opening in the side of the box

on account of a small amount of light being
the amount. It is therefore, in general, the
light in the standard, the intensity is not as
the proper value.

The light from the comparison lamp falls upon
a white glass plate which is placed through the
aperture. The intensity of the light from
this plate is seen to vary inversely as the
square of the distance from the comparison
source by seeing the light of the two plates
and introducing a system of neutral glass between
which however any light from either lamp the
plate except that which comes from the comparison
lamp source.

The scale upon which the readings are in-
duced is made of translucent celluloid and
is illuminated by means of a small slit in the
middle of the comparison lamp so that it
may be read in day light as well as at
night light. The scale is graduated with an
inverted-image scale and is placed over a
longitudinal opening in the side of the box

so that it may be observed from the outside. There is a shutter which may be dropped over the screen so that the observer will not be influenced by previous readings.

The elbow tube at the end of the box is fitted friction-tight on a collar so that it may be rotated through any angle about a horizontal axis. The angle is indicated by means of a pointer on the elbow and a semi-circular scale upon the box. The tube furnishes the simplest means of measuring illumination or light coming from and direction. A reversible plate is fixed in the elbow of the tube; one side of which may be used in measuring candle power; and the other side, which is a mirror may be used in measuring illumination.

Where intense illumination is to be measured an absorbing plate or screen is inserted between the elbow tube and the screen, thus bringing the illumination on the field to such a value that a balance may be obtained.

as that it may be observed that the
there is a certain width and the
the system as that the operation will not be
illustrated by reference to the

The above is at the end of the 14-15-
Let the above be a circle and let it be
be pointed through and angle about a horizontal
axis. The angle is indicated by means of a
pointer on the above and a semi-circular scale
upon the box. The angle through the circle
means of measuring illumination at right angles
from the horizontal. A vertical plate is
fixed in the edge of the tube; one side of
which may be used in measuring angle of view
and the other side, which is a mirror, may be
used in measuring illumination.

Many factors illumination is to be measured
and an illuminated plate or screen is inserted
between the above tube and the screen. The
reading the illumination on the plate is then
obtained that a balance may be obtained.

CHAPTER III

Preliminary Calculations

Probably the first thing to do in making a test of any kind is to calibrate the instruments to be used. In this test two voltmeters and two ammeters were used. By means of a potentiometer, it was found that one voltmeter read correctly, while the other was four-tenths of a volt high from one hundred volts up to one hundred and twenty volts. The ammeter used in the test was found to read three-hundredths of an ampere low between the limits of the current used in the test.

Having obtained calibrated instruments, the next step is to determine the mean spherical candle-power of the lamp which in this case was a nitrogen-filled, 300-watt tungsten lamp. This is done in the following manner: a calibrated vacuum lamp from the Electrical Testing Laboratory is used as a standard. In order that this lamp shall not be burned for

APPENDIX

EXPERIMENTAL RESULTS

1. The first experiment was conducted with a

view of the fact that the results of the

experiment were not in accordance with the

theoretical results. It was found that the

results of the experiment were not in accordance

with the theoretical results. It was found

that the results of the experiment were not

in accordance with the theoretical results.

The results of the experiment were not in

accordance with the theoretical results.

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results of the experiment were not in

accordance with the theoretical results.

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accordance with the theoretical results.

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results of the experiment were not in

accordance with the theoretical results.

The results of the experiment were not in

any great length of time, thus changing its candle power, a secondary standard is obtained. This is done by placing the standard lamp at one end of the photometer bench and the secondary standard at the other end with the photometer head midway between them. With this setting, the voltage on the secondary standard is changed until a balanced condition on the photometer is obtained; its horizontal candle-power in this particular position, and at this particular voltage is now equal to that of the original standard, and may itself be used as a primary standard. In this test, a 220c.p. vacuum lamp (#4577) was used as a primary standard and was to be worked at 110.4 volts and 2.075 amperes. The voltage of the secondary standard to give the same candle-power was found to be 111.24 volts.

The next step is to determine the mean horizontal candle-power (m.h.c.p.) of a lamp whose reduction factor is known. This is determined

... (1) ... (2) ... (3) ... (4) ... (5) ... (6) ... (7) ... (8) ... (9) ... (10) ... (11) ... (12) ... (13) ... (14) ... (15) ... (16) ... (17) ... (18) ... (19) ... (20) ... (21) ... (22) ... (23) ... (24) ... (25) ... (26) ... (27) ... (28) ... (29) ... (30) ... (31) ... (32) ... (33) ... (34) ... (35) ... (36) ... (37) ... (38) ... (39) ... (40) ... (41) ... (42) ... (43) ... (44) ... (45) ... (46) ... (47) ... (48) ... (49) ... (50) ... (51) ... (52) ... (53) ... (54) ... (55) ... (56) ... (57) ... (58) ... (59) ... (60) ... (61) ... (62) ... (63) ... (64) ... (65) ... (66) ... (67) ... (68) ... (69) ... (70) ... (71) ... (72) ... (73) ... (74) ... (75) ... (76) ... (77) ... (78) ... (79) ... (80) ... (81) ... (82) ... (83) ... (84) ... (85) ... (86) ... (87) ... (88) ... (89) ... (90) ... (91) ... (92) ... (93) ... (94) ... (95) ... (96) ... (97) ... (98) ... (99) ... (100) ...

The new standard is set at one end of the photometer bench in the proper position, and working at the voltage found (111.24). The comparison lamp is placed at the other end of the bench and is worked at 110 volts. By changing the position of photometer head, a balance can be obtained and the candle-power of the comparison lamp calculated from the equation:

$$I_x = I_o \frac{r_x^2}{r_o^2}, \text{ where}$$

I_x = candle-power of comparison lamp

I_o = candle-power of standard lamp

r_x = distance between screen and comparison

r_o = distance between screen and standard

This value having been obtained, the comparison lamp is rotated ten degrees at a time and the candle-power for each position is calculated. The average of the values obtained gives the m.h.c.p. The mean spherical candle-power (m.s.c.p.) is found by multiplying the m.h.c.p. by the reduction factor. The lamp used had a

The new standard is used at all times in the position
 with regard to the system position, and verified
 at the village (June 1911.1912). The comparison
 lamp is placed at the other end of the beam
 and is worked at 110 volts. By changing the
 position of photometer head, a balance can be
 obtained and the candle-power of the comparison
 lamp calculated from the equation:

$$L_x = L_o \frac{R_o^2}{R_x^2} \text{ where}$$

- L_x = candle-power of comparison lamp
 - L_o = candle-power of standard lamp
 - R_x = distance between source and comparison
 - R_o = distance between source and standard
- This value having been obtained, the comparison
 lamp is rotated and decentered at a time and the
 candle-power for each position is calculated.
 The average of the values obtained gives the
 c.p.d. The mean spherical candle-power
 (c.s.p.) is found by multiplying the c.p.d.
 by the reduction factor. The lamp used has a

m.h.c.p. of 210, and a reduction factor of .78. This gave the m.s.c.p. as 164.

To calibrate the globe photometer now is a simple matter. The lamp with the known m.s.c.p. is placed inside the globe and the Sharp-Millar photometer is set to read the m.s.c.p. directly. The voltage on the Sharp-Millar is then adjusted until the illumination on the screen is balanced. Thus a direct-reading photometer for m.s.c.p. is obtained, providing, of course, that the Sharp-Miller photometer is worked at the above determined voltage. If the comparison lamp is replaced by a lamp of unknown m.s.c.p. such as the nitrogen lamp, its m.s.c.p. can be directly determined by obtaining a balance on the S-M photometer by moving its lamp to or from the screen. The m.s.c.p. can be read directly from the scale. In the case of the nitrogen lamp, it was found to be 284 c.p.

In expressing the efficiency of a lamp, it has long been the custom to express it as so

1.1.1. of 100, and a constant factor of 10.

The wave the d.c.p. is 100.

To calculate the globe photometer now is a

simple matter. The lamp with the known c.p.d.

is placed inside the globe and the photometer

photometer is set to read the c.p.d. directly.

The voltage on the photometer is then adjusted

until the illumination on the screen is uniform.

There is direct-reading photometer for c.p.d. is

obtained, provided, of course, that the photometer

photometer is used at the same distance

as the comparison lamp is to

be used in a lamp of unknown c.p.d. and on

the other hand, the c.p.d. can be directly

determined by obtaining a balance on the

photometer by moving the lamp to or from the

screen. The c.p.d. can be read directly from

the scale. In the case of the direct lamp,

it was found to be 100 c.p.d.

To represent the efficiency of a lamp, it

has been the custom to express it as a

many lumens per watt. The reason for this is simple and becomes apparent with a little consideration; with the recent development in shades, reflectors, etc. the h.c.p. has very little to do with the resultant illumination; it is the total number of lumens given off that affects this. The total number of lumens given off is equal to $4\pi \times \text{m.s.c.p.}$ It was, therefore, for this lamp $4\pi \times 278 = 3500$ lumens. The number of watts consumed was 269, and its efficiency was, therefore, $\frac{3500}{269} = 13$ lumens per watt.

The lamp is now ready to be put in place and its distribution curve determined. Before doing this, however, it is necessary to calibrate the Sharp-Miller photometer, so that it will read foot-candles illumination directly. This is done in the following manner: A standard 32 c.p. lamp was used and placed at such a distance away that there was an illumination of one foot-candle on the photometer. This distance was determined from the

many times per day. The reason for this is
 always and human contact with a little more
 attention: with the present development in
 science, technology, etc. the human race may
 decide to do with the present civilization
 it is the total number of human beings on the
 earth. This is the total number of human beings
 on the earth in 4-5 a.m. is now, therefore,
 for this time is 4-5 a.m. is now. The
 number of people known was 100, and the 10-
 billion was, therefore, $\frac{1000}{100} = 10$ billion per
 unit.

The time is now ready to be put in place
 and the situation have determined. Before
 doing this, however, it is necessary to re-
 form the group-like structure, so that
 it will need four-tennis illustrations. It
 is. This is done in the following manner:
 according to the 10-10 group and placed in
 with a diagram that there are 10-
 formation of one four-tennis on the whole
 action. This situation has determined that the

equation:

$$E = \frac{I}{r^2} \quad \text{and} \quad r = \sqrt{\frac{I}{E}}$$

$$I = 32 \text{ c.p.} \quad E = 1 \text{ ft. candle}$$

$$r = \sqrt{32} = 5.66'$$

The scale on the photometer was then set to read 1 ft. candle and a balance was obtained by adjusting the voltage to the proper value. If for any value of illumination, this current is kept at the above value and the photometer lamp is adjusted to a balance, the scale will read the foot-candles illumination directly. For very low illumination, the photometer lamp is too bright and a screen must be used. The screen used in this case was found to multiply the actual illumination by 18.74; i.e., the scale reading must be divided by 18.74 to get the true illumination.

equation:

$$I = \frac{V}{R} \quad (1)$$
$$I = \frac{V}{R} \quad (2)$$
$$I = \frac{V}{R} \quad (3)$$

The scale on the photometer was then set to read 1 ft. candle and a balance was obtained by adjusting the voltage to the proper value. If for any value of illumination, this current is kept at the above value and the photometer lamp is adjusted to a balance, the scale will read the foot-candle illumination directly. For very low illumination, the photometer lamp is too bright and a screen must be used. The screen used in this case was found to multiply the normal illumination by 15.74: i.e., the scale reading must be divided by 15.74 to get the true illumination.

CHAPTER IV

Actual Work and Results

The main purpose of this test was to determine the proper relation of the ceiling, lamp and bowl with respect to each other. To do this, a series of runs were made for different positions and the distribution curves plotted. The stations or points of measurement were three feet apart to a distance of twenty-one feet. A group of data was taken under the following conditions: the size of the ceiling was fixed at 6' 0" x 6' 0"; second, the distance between the ceiling and lamp was fixed; and third, six positions of the bowl with respect to the ceiling were used and curves plotted. This set of data comprises the group of curves given on Chart #I. Similar groups of curves were plotted for seven other distances between the lamp and the ceiling, and the results plotted and given in Charts #1 to #8 inclusive. A similar set

VI. CONCLUSIONS

1. General Remarks and Conclusions

The main purpose of this paper was to determine the proper relation of the calling and how it is related to each other. To do this, a series of tests were made for the various positions and the distribution curves plotted. The relation of points of maximum and minimum was then plotted to a distance of twenty-five feet. A group of data was taken under the following conditions: the size of the calling was fixed at 0' 0" and 0' 0"; second, the distance between the calling and the boat was fixed; and third, the conditions of the boat with respect to the calling were fixed and curves plotted. The set of data comprised the group of curves shown on Chart II. Similar groups of curves were plotted for seven other distances between the boat and the calling, and the results plotted and given in Charts III to IX inclusive. A similar set

of data, as above mentioned, was taken for a smaller ceiling which was 4' 3" in diameter. The results obtained were plotted and are given in Charts #1_a to #7_a inclusive.

A secondary purpose of this test was to determine the distribution curves of several enclosing globes for nitrogen lamps and to determine the absorption coefficient of each. Three enclosed globes were used, one from the Macbeth Co. and two acorns of different size from the Gill Co. A distribution curve was also taken for an X-Ray reflector. These curves are all given on Chart A. To determine the absorption coefficient, the bare lamp was placed inside the globe potentiometer and the Sharp-Millar photometer was read. The enclosing globe was then placed over the lamp and the photometer read again. The ratio of these two readings gave the percent light transmitted, and 100% minus this gave the absorption coefficients. These latter tests were made with a 200-watt

These findings were made with a 100-watt
ultraviolet light source and a 100-watt
infrared light source. The results were
the same for both sources. The results
were also the same for both sources.
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sources. The results were also the same
for both sources. The results were also
the same for both sources. The results
were also the same for both sources.

nitrogen lamp.

A summary of the important facts relating to this test is given below.

Best position of lamp	(
and bowl with respect	(Lamp 21 " below ceiling
to 6' 0" ceiling	(Bowl 23.75" " "
	(

Best position of lamp	(
and bowl with respect	(Lamp 14.5" below ceiling
to 4' 3" ceiling	(Bowl 17.25" " "
	(

Absorption Coefficient of Maabbeth globe = 15.6%

"	"	"	Gill large acorn = 21.9%
"	"	"	" small " = 27.5%

4

...and the ...

" " " " " "

" " " " " "

I Form



... ..

Left position of lamp	{	Left position of lamp
Left lamp with respect		Left lamp with respect
Left lamp 12.75"		Left lamp 12.75"

Left position of lamp	{	Left position of lamp
Left lamp with respect		Left lamp with respect
Left lamp 12.75"		Left lamp 12.75"

Left position of lamp = 12.75"

Left lamp with respect	"	"	"
Left lamp 12.75"	"	"	"

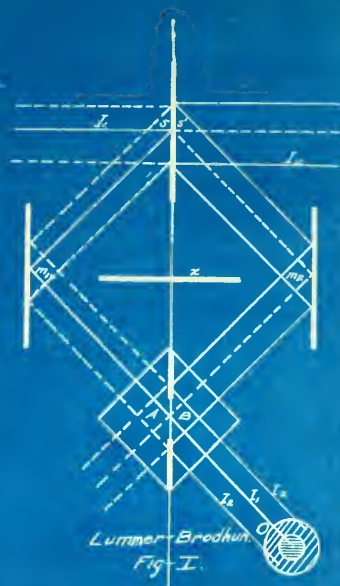


Fig. II.



Fig. III.

Globe Photometer.

M.H.C.P. of SECONDARY STANDARD.

Scale Reading	Degrees	Scale Reading	Degrees	Scale Reading	Degrees	Scale Reading	Degrees	Scale Reading	Degrees
126.8	0	126.6	80	125.7	160	125.9	240	125.7	320
125.8	10	126.8	90	126.7	170	126.8	250	129.4	330
126.4	20	125.9	100	125.7	180	125.7	260	126.0	340
128.0	30	126.6	110	126.6	190	127.8	270	126.4	350
125.8	40	127.5	120	126.1	200	126.8	280	126.6	360
126.9	50	125.6	130	125.5	210	125.7	290		
126.3	60	126.6	140	126.5	220	126.5	300		
126.3	70	127.4	150	125.7	230	125.6	310		

M.H.C.P. = 210.4

M.S.C.P. = 164.0

M.S.C.P. of 300 watt nitrogen-filled bulb = 277.9

Volts = 110.

Amperes = 2.45

Efficiency = 12.98 lumens per watt.

M.S.C.P. of 200 watt nitrogen-filled bulb = 279.8

Volts = 115.

Amperes = 1.975

Efficiency = 15.40 lumens per watt.

*FT.-CANDLE ILLUMINATION ON PLANE 13 FT. FROM REFLECTING SURFACE, (6'x6').
300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.*

DISTANCE FROM CEILING TO		STATIONS, (3' APART)							
BOTTOM OF BULB	CENTER OF FILAMENT	1	2	3	4	5	6	7	8
23.75"	21"	2.34	2.13	1.73	1.05	0.61	0.32	0.19	0.12
24.25"		2.18	2.00	1.51	1.03	0.61	0.32	0.19	0.12
24.875"		2.05	1.89	1.40	0.93	0.53	0.32	0.18	0.12
25.5"		1.95	1.75	1.30	0.84	0.48	0.28	0.17	0.10
26.15"		1.95	1.71	1.19	0.68	0.36	0.26	0.17	0.10
26.75"		1.66	1.58	1.18	0.72	0.34	0.24	0.15	0.09
23.25"	20.5"	2.19	2.02	1.42	0.94	0.53	0.30	0.17	0.11
23.75"		2.10	1.86	1.36	0.85	0.53	0.27	0.17	0.11
24.375"		1.99	1.77	1.36	0.73	0.49	0.28	0.18	0.10
25.0"		2.05	1.78	1.36	0.73	0.49	0.28	0.16	0.10
25.65"		2.06	1.81	1.24	0.82	0.46	0.28	0.16	0.10
26.25"		1.84	1.61	1.22	0.77	0.45	0.27	0.15	0.09
22.25"	19.5"	2.27	1.93	1.53	0.94	0.56	0.34	0.19	0.12
22.75"		2.14	1.91	1.43	0.92	0.49	0.31	0.18	0.11
23.375"		2.12	1.75	1.40	0.89	0.49	0.28	0.17	0.10
24.0"		2.01	1.82	1.33	0.86	0.44	0.28	0.17	0.10
24.65"		1.93	1.61	1.29	0.75	0.46	0.26	0.16	0.10
25.25"		1.87	1.67	1.17	0.74	0.43	0.25	0.15	0.09
21.25"	18.5"	2.26	1.95	1.58	0.97	0.54	0.31	0.20	0.12
21.75"		2.15	1.97	1.49	0.94	0.52	0.30	0.18	0.11
22.375"		2.15	1.90	1.31	0.86	0.50	0.29	0.18	0.11
23.0"		2.06	1.84	1.33	0.90	0.48	0.29	0.15	0.11
23.65"		2.03	1.74	1.30	0.85	0.49	0.29	0.17	0.11
24.25"		1.82	1.76	1.24	0.81	0.43	0.27	0.16	0.11

FT.-CANDLE ILLUMINATION ON PLANE 13 FT. FROM
REFLECTING SURFACE (6'x6').
300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.

DISTANCE FROM CEILING TO		STATIONS, (3' APART)							
BOTTOM OF BOWL	CENTER OF FILAMENT	1	2	3	4	5	6	7	8
20.25"	17.5"	2.13	1.99	1.49	0.99	0.50	0.32	0.19	0.13
20.75"		2.08	1.99	1.49	0.96	0.49	0.30	0.19	0.13
21.375"		2.15	1.99	1.50	0.95	0.51	0.30	0.17	0.13
22.0"		2.08	1.90	1.26	0.77	0.43	0.25	0.14	0.09
22.65"		1.96	1.66	1.23	0.74	0.40	0.25	0.17	0.10
23.25"		1.85	1.66	1.23	0.74	0.40	0.23	0.15	0.09
19.25"	16.5"	2.20	2.05	1.55	0.94	0.53	0.33	0.18	0.11
19.75"		2.23	2.06	1.46	0.92	0.50	0.32	0.19	0.13
20.375"		2.11	1.97	1.34	0.86	0.49	0.28	0.17	0.11
21.0"		1.97	1.78	1.24	0.76	0.46	0.28	0.14	0.10
21.65"		1.83	1.65	1.20	0.73	0.43	0.26	0.15	0.09
22.25"		1.89	1.63	1.18	0.79	0.41	0.26	0.15	0.10
18.25"	15.5"	2.24	2.09	1.52	0.91	0.53	0.32	0.20	0.12
18.75"		2.11	2.00	1.41	0.88	0.52	0.30	0.18	0.10
19.375"		2.02	1.88	1.44	0.92	0.51	0.28	0.18	0.10
20.0"		1.99	1.83	1.31	0.88	0.45	0.27	0.17	0.10
20.65"		1.93	1.77	1.34	0.87	0.49	0.29	0.18	0.12
21.25"		1.99	1.83	1.34	0.90	0.50	0.30	0.17	0.11
17.25"	14.5"	2.37	2.13	1.52	1.00	0.53	0.34	0.19	0.12
17.75"		2.23	2.02	1.48	1.01	0.52	0.33	0.20	0.13
18.375"		2.18	1.98	1.50	1.00	0.52	0.32	0.20	0.12
19.0"		2.19	1.99	1.42	0.93	0.49	0.31	0.19	0.11
19.65"		2.06	2.00	1.44	0.90	0.49	0.31	0.19	0.12
20.25"		1.92	1.72	1.26	0.86	0.46	0.29	0.16	0.11

FT. CANDLE ILLUMINATION ON PLANE 13 FT. FROM
REFLECTING SURFACE, (DIAM. 4.25').
300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.

DISTANCE FROM CEILING TO		STATIONS (3'apart).							
BOTTOM OF BOWL	CENTER OF FILAMENT	1	2	3	4	5	6	7	8
23.25"	20.5"	1.40	1.35	1.03	0.61	0.38	0.22	0.12	0.09
23.75"		1.31	1.28	0.96	0.55	0.35	0.21	0.12	0.09
24.375"		1.33	1.25	0.90	0.54	0.32	0.21	0.12	0.09
25.0"		1.26	1.23	0.90	0.54	0.35	0.21	0.12	0.08
25.65"		1.26	1.23	0.88	0.53	0.32	0.19	0.12	0.08
26.25"		1.23	1.12	0.84	0.50	0.30	0.19	0.12	0.07
22.25"	19.5"	1.38	1.33	0.95	0.56	0.35	0.24	0.14	0.08
22.75"		1.34	1.25	0.92	0.54	0.31	0.21	0.13	0.08
23.375"		1.34	1.26	0.96	0.54	0.34	0.22	0.13	0.08
24.0 "		1.33	1.22	0.94	0.53	0.34	0.21	0.12	0.09
24.65"		1.29	1.26	0.96	0.54	0.34	0.22	0.12	0.08
25.25"		1.31	1.13	0.91	0.53	0.31	0.21	0.12	0.08
21.25"	18.5"	1.65	1.44	1.13	0.71	0.38	0.24	0.16	0.09
21.75"		1.64	1.42	1.09	0.70	0.37	0.23	0.14	0.08
22.375"		1.45	1.34	0.95	0.68	0.36	0.23	0.14	0.08
23.0"		1.35	1.17	0.93	0.54	0.32	0.21	0.14	0.08
23.65"		1.31	1.13	0.93	0.54	0.33	0.21	0.12	0.08
24.25"		1.31	1.14	0.90	0.52	0.34	0.20	0.13	0.08
20.25"	17.5"	1.61	1.45	1.13	0.72	0.41	0.24	0.15	0.08
20.75"		1.53	1.39	1.09	0.69	0.39	0.23	0.14	0.08
21.375"		1.51	1.41	1.04	0.65	0.37	0.23	0.14	0.08
22.0 "		1.32	1.23	0.97	0.62	0.33	0.19	0.12	0.07
22.65"		1.35	1.25	0.94	0.60	0.33	0.21	0.13	0.07
23.25"		1.34	1.18	0.87	0.56	0.32	0.21	0.12	0.07

**FT. CANDLE ILLUMINATION ON PLANE 13 FT. FROM
REFLECTING SURFACE (DIAM. 425').
300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.**

DISTANCE FROM CEILING TO BOTTOM CENTER OF BULB FILAMENT		STATIONS (3' apart)							
		1	2	3	4	5	6	7	8
19.25"	16.5"	1.53	1.41	1.01	0.66	0.34	0.22	0.13	0.09
19.75"		1.46	1.30	1.00	0.62	0.32	0.20	0.13	0.08
20.375"		1.38	1.23	0.95	0.60	0.33	0.22	0.13	0.08
21.0"		1.32	1.19	0.93	0.62	0.32	0.21	0.13	0.08
21.65"		1.31	0.18	0.89	0.56	0.33	0.19	0.13	0.08
22.25"		1.21	1.09	0.84	0.54	0.30	0.18	0.12	0.07
18.25"	15.5"	1.91	1.79	1.31	0.77	0.40	0.24	0.15	0.08
18.75"		1.69	1.50	1.16	0.69	0.39	0.22	0.13	0.09
19.375"		1.73	1.52	1.14	0.71	0.39	0.22	0.15	0.09
20.0"		1.79	1.50	1.15	0.68	0.37	0.23	0.14	0.09
20.65"		1.51	1.38	1.13	0.62	0.35	0.20	0.14	0.08
21.25"		1.56	1.47	1.16	0.71	0.40	0.24	0.15	0.09
17.25"	14.5"	1.88	1.81	1.26	0.91	0.49	0.27	0.17	0.12
17.75"		1.94	1.72	1.22	0.83	0.43	0.25	0.15	0.10
18.375"		1.71	1.54	1.15	0.77	0.41	0.26	0.15	0.10
19.0"		1.57	1.38	1.12	0.70	0.39	0.25	0.14	0.10
19.65"		1.52	1.41	1.02	0.70	0.36	0.22	0.14	0.09
20.25"		1.42	1.31	1.01	0.70	0.35	0.20	0.14	0.08

FT.-CANDLE ILLUMINATION ON PLANE 14 FT. FROM CEILING.
 200 WATT NITROGEN-FILLED LAMP WITH DIFFERENT ENCLOSING GLOBES.
 CENTER OF GLOBES 2 FT. FROM CEILING.

MACBETH

STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	3.04	1.95	1.62	1.00	0.61	0.42	0.27	0.18

200 WATT ACORN

STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	2.14	1.88	1.36	0.85	0.53	0.31	0.21	0.13

100 WATT ACORN

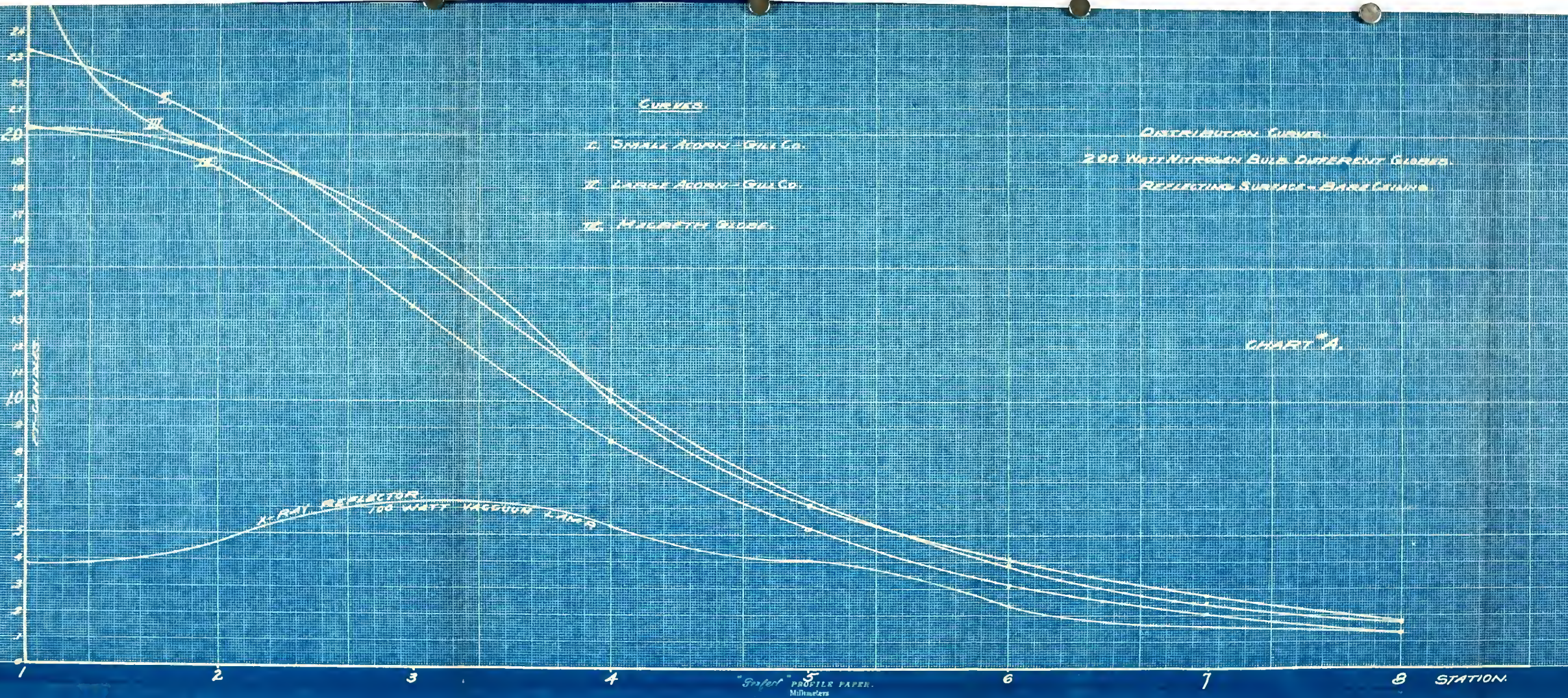
STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	2.33	2.03	1.55	1.05	0.61	0.39	0.25	0.17

X-RAY REFLECTOR WITH 100 WATT VACUUM BULB.

STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	0.38	0.46	0.63	0.53	0.41	0.24	0.18	0.09

ABSORPTION COEFFICIENTS

	BARE BULB	Bulb enclosed by Macbeth globe	Bulb enclosed by 200 watt Acorn	Bulb enclosed by 100 watt Acorn
M.S.C.P.	200	168.8	156.3	145.0
% Absorption		15.6 %	21.9 %	27.5 %



CURVES

I. SMALL AGORN - GIL CO.

II. LARGE AGORN - GIL CO.

III. MILDRETH GILCO.

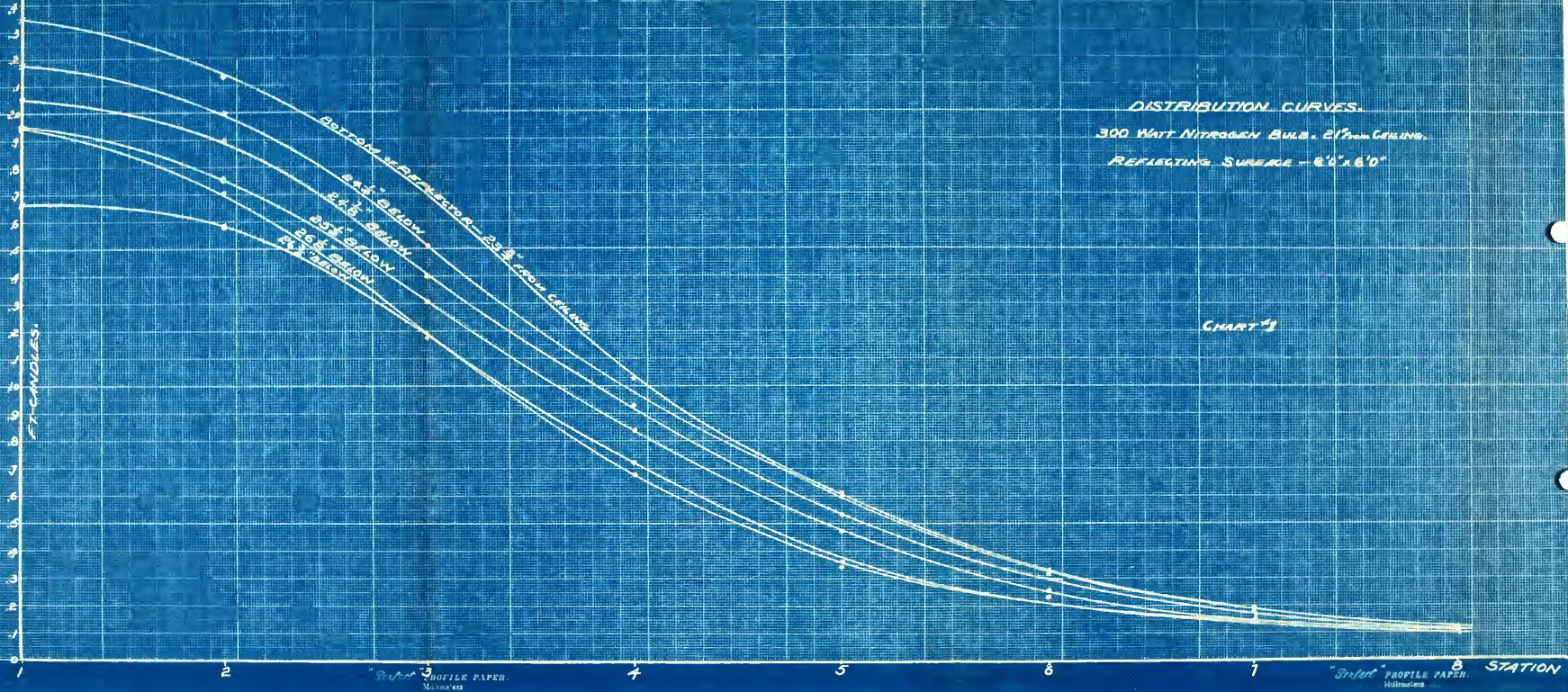
DISTRIBUTION CURVES

200 WATT NITROGEN BULB DIFFERENT GLASSES

REFLECTING SURFACE - BARE GLASS

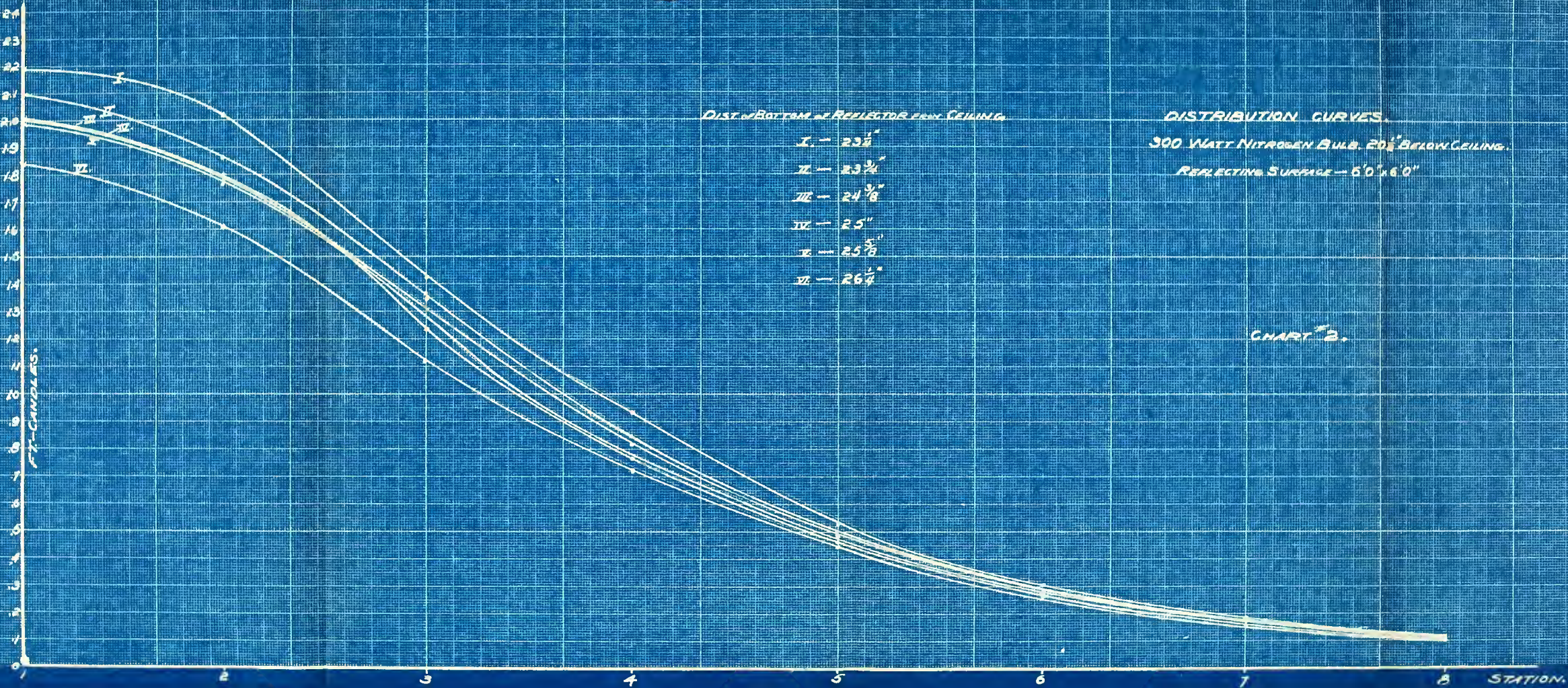
CHART #A.

100 WATT VACUUM 2.5MPS



DISTRIBUTION CURVES.
300 Watt Nitrogen Bulb - 2 1/2 inch Ceiling.
REFLECTING SURFACE - 6'0" x 6'0"

CHART 43



DIST. BOTTOM OF REFLECTOR FROM CEILING

I - 18 $\frac{1}{2}$ "

II - 18 $\frac{3}{4}$ "

III - 19 $\frac{1}{2}$ "

IV - 20"

V - 20 $\frac{5}{8}$ "

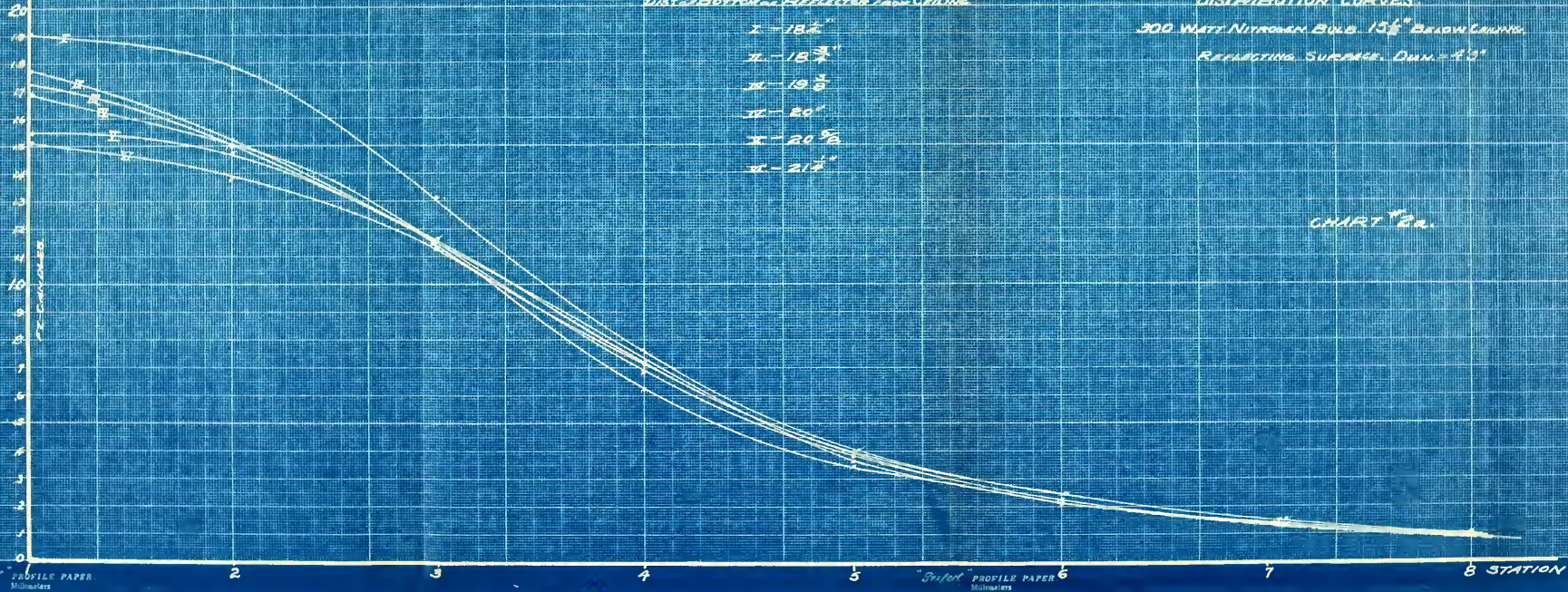
VI - 21 $\frac{1}{2}$ "

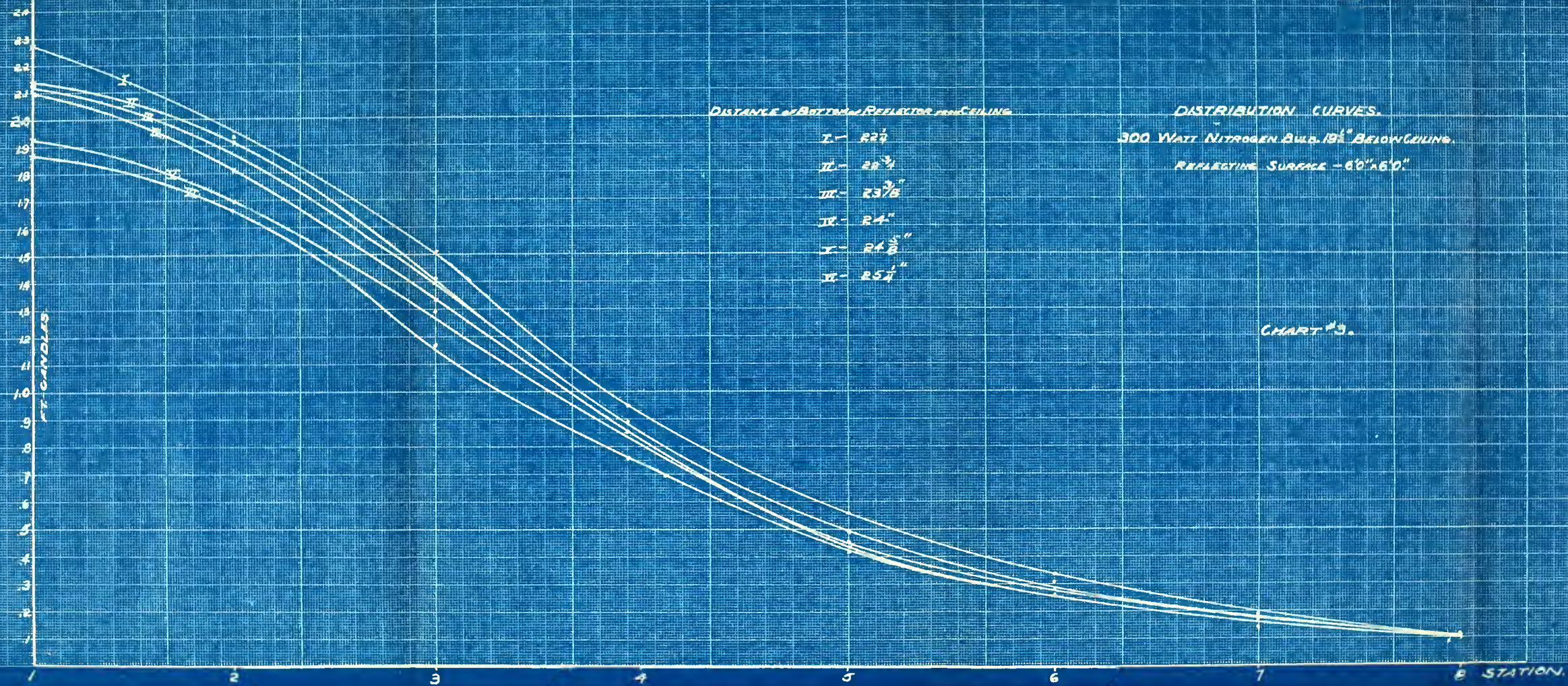
DISTRIBUTION CURVES

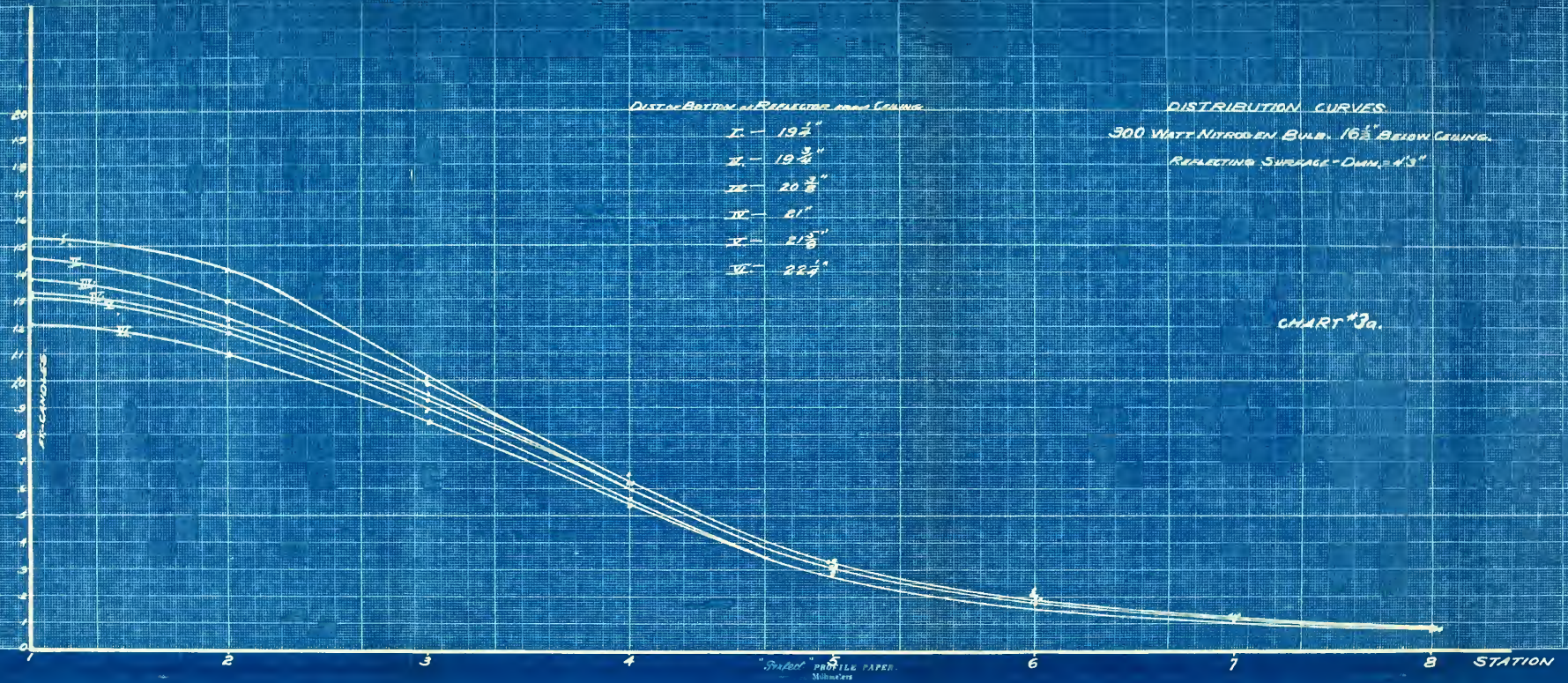
300 WATT NITROGEN BULB. 13 $\frac{1}{2}$ " BELOW CEILING.

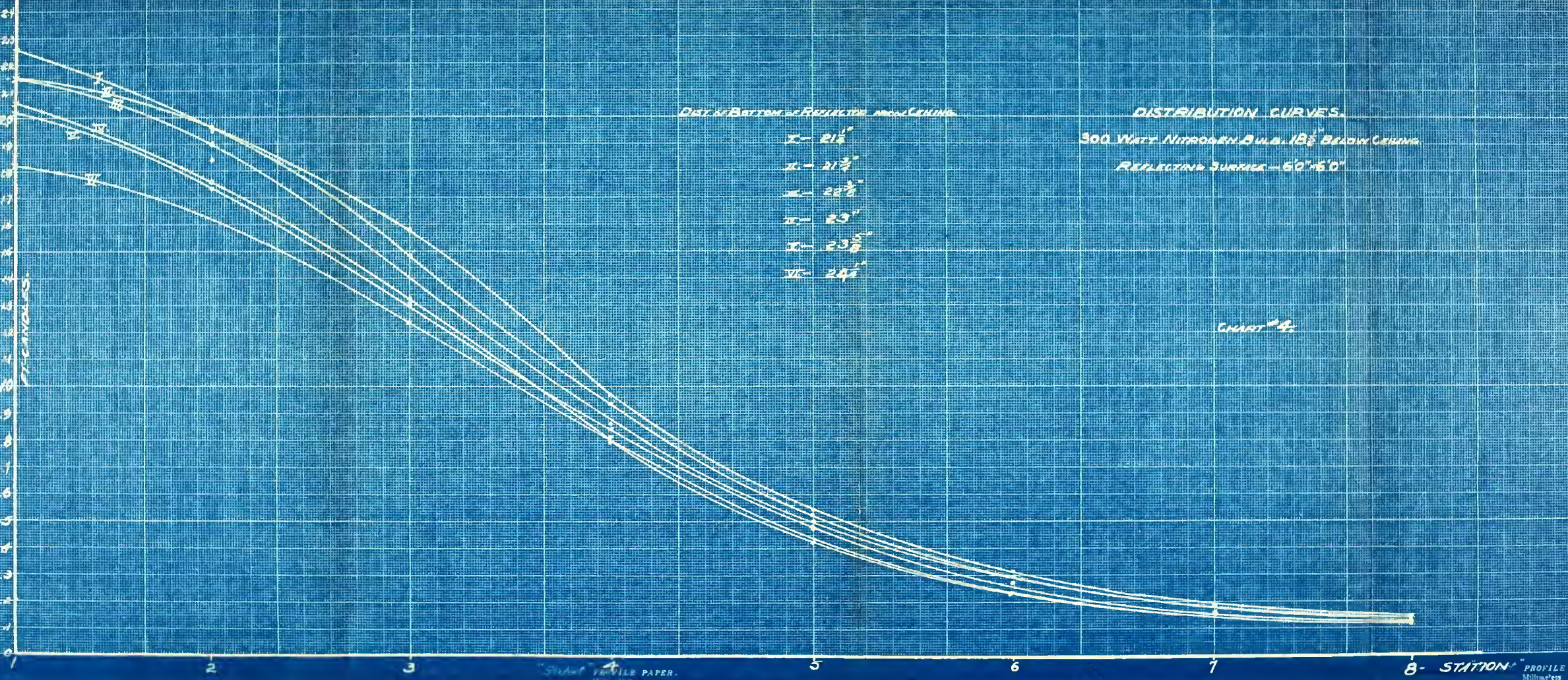
REFLECTING SURFACE. DIA. = 4' 9"

CHART #22.



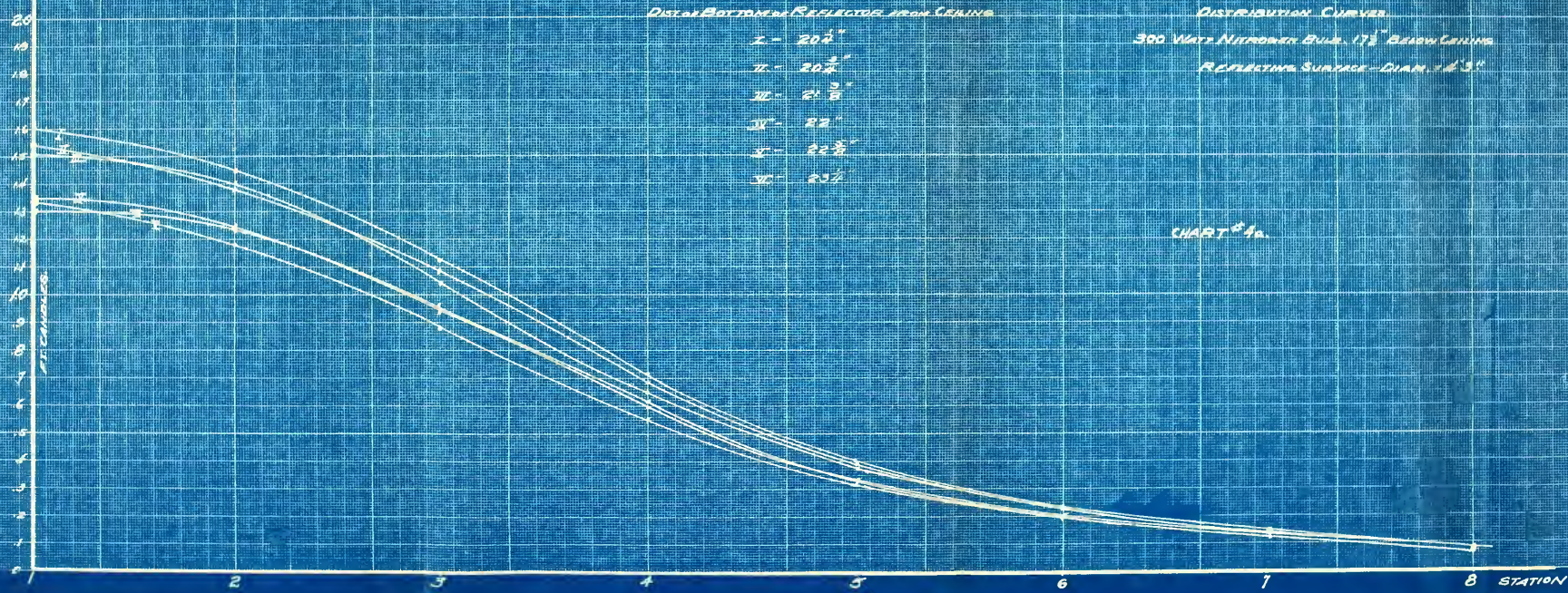


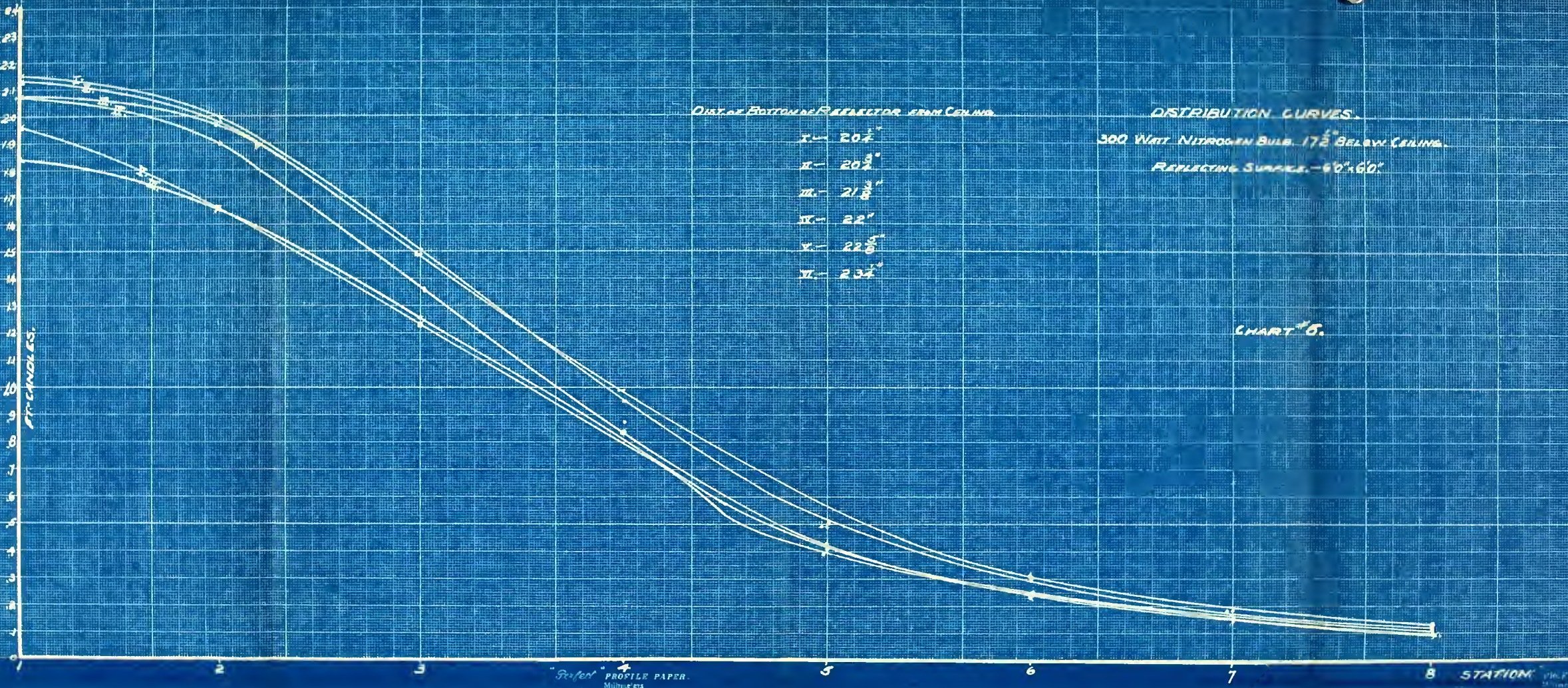




"SUN" PROFILE PAPER
 MILLIMETERS

PROFILE PAPER
 MILLIMETERS





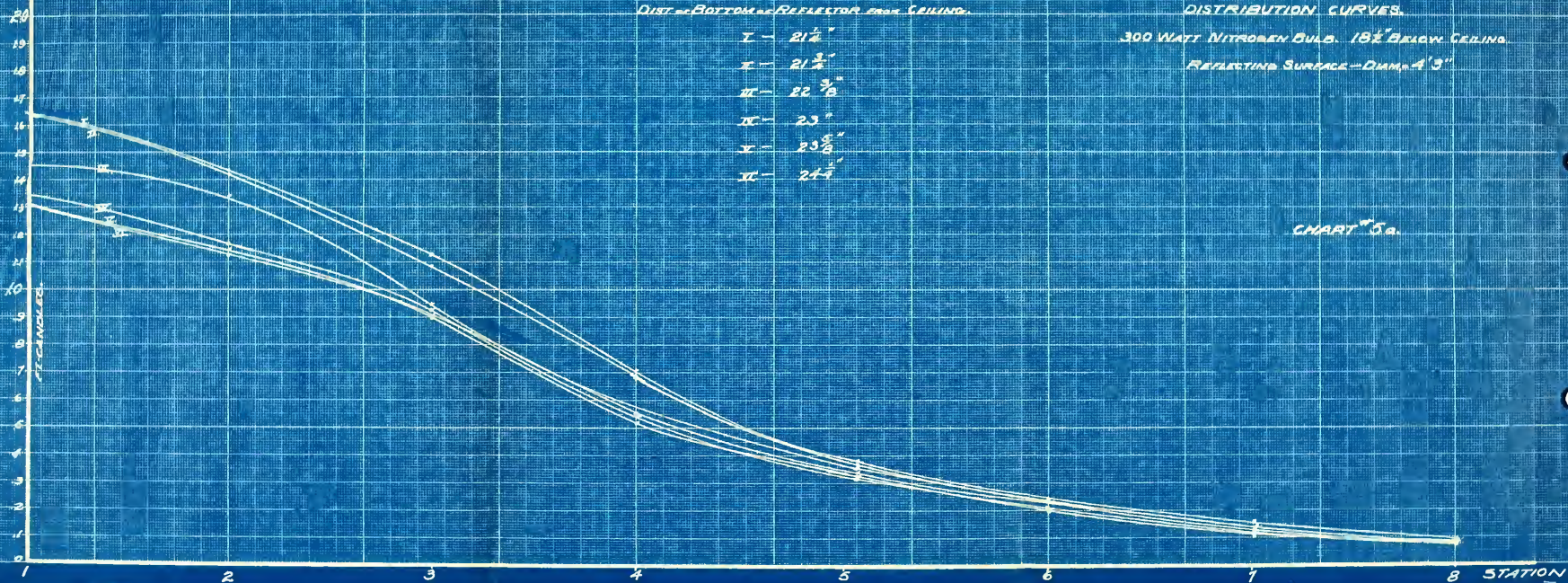
DIST. OF BOTTOM REFLECTOR FROM CEILING

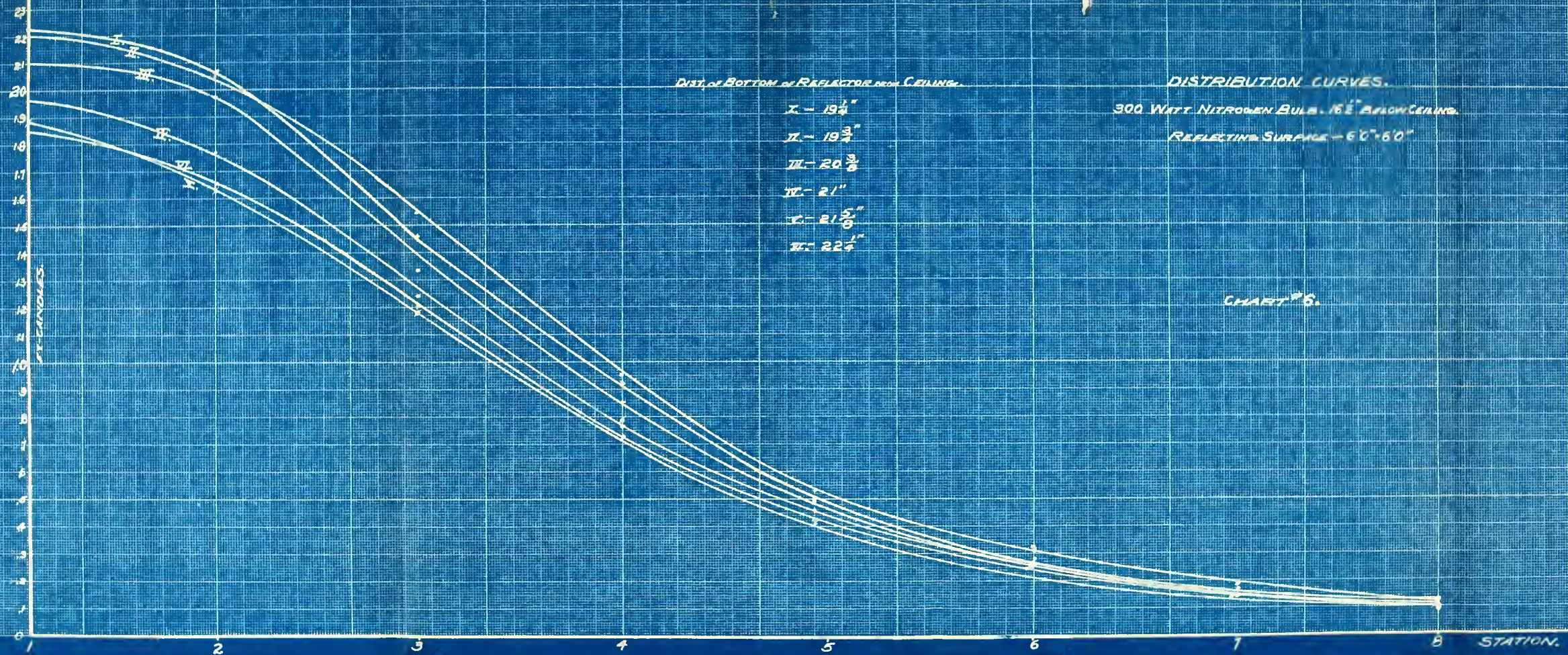
- I - 20 1/2"
- II - 20 3/4"
- III - 21 3/8"
- IV - 22"
- V - 22 5/8"
- VI - 23 1/4"

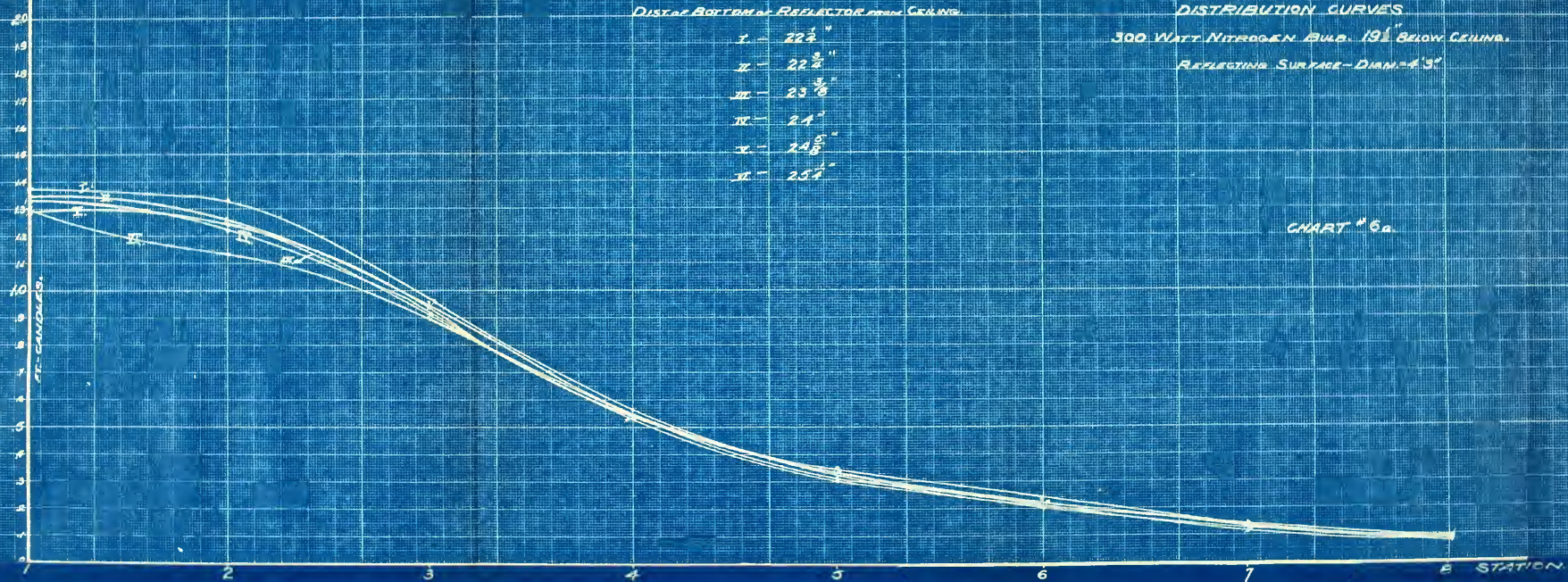
DISTRIBUTION CURVES.

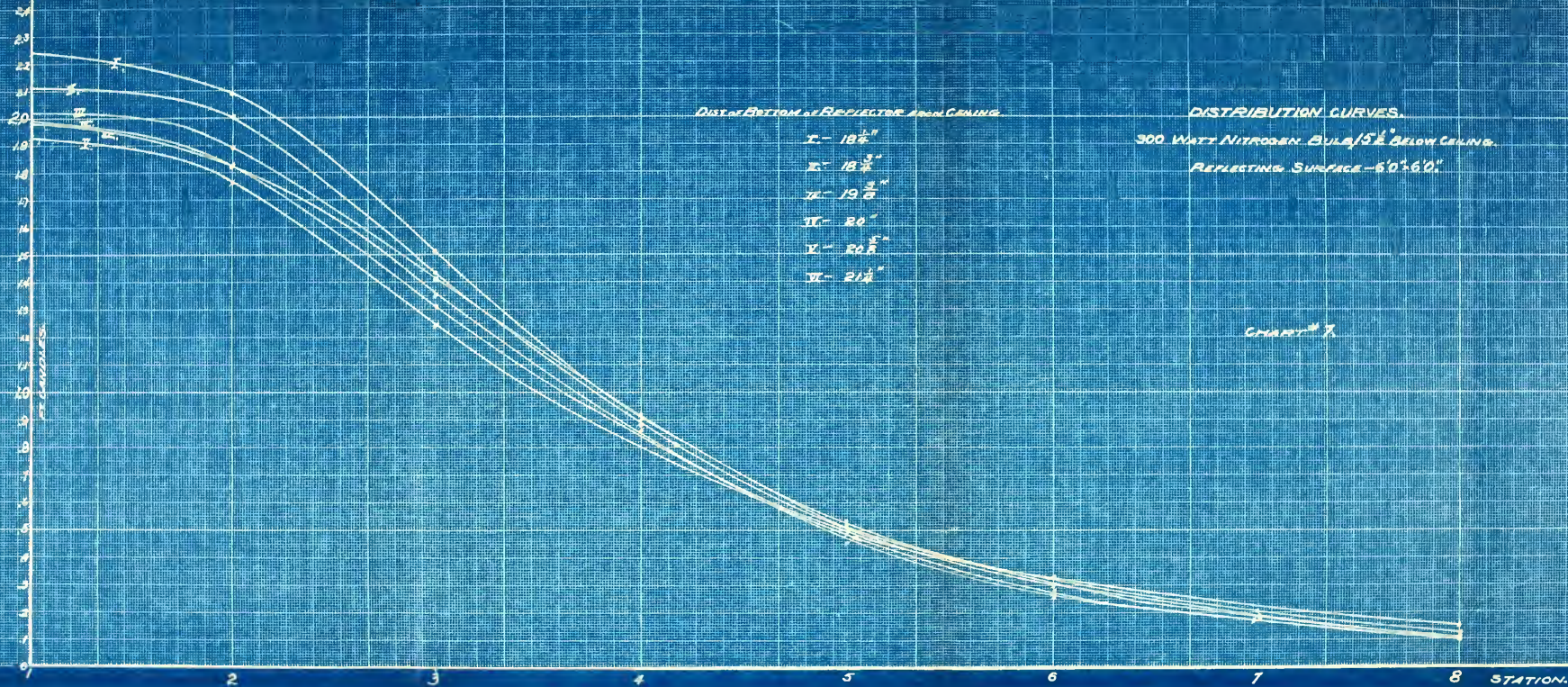
300 Watt NITROGEN BULB. 17 1/2" BELOW CEILING.
 REFLECTING SURFACE - 60" x 60"

CHART #5.









20

18

16

14

12

10

8

6

4

2

0

STANDARD

2

3

5

6

7

8

"Griff" PROFILE PAPER
Millimeters

DISTANCE FROM REFLECTOR TO CEILING

I - 23 1/2"

II - 23 3/4"

III - 24 1/2"

IV - 25"

V - 25 1/2"

VI - 26"

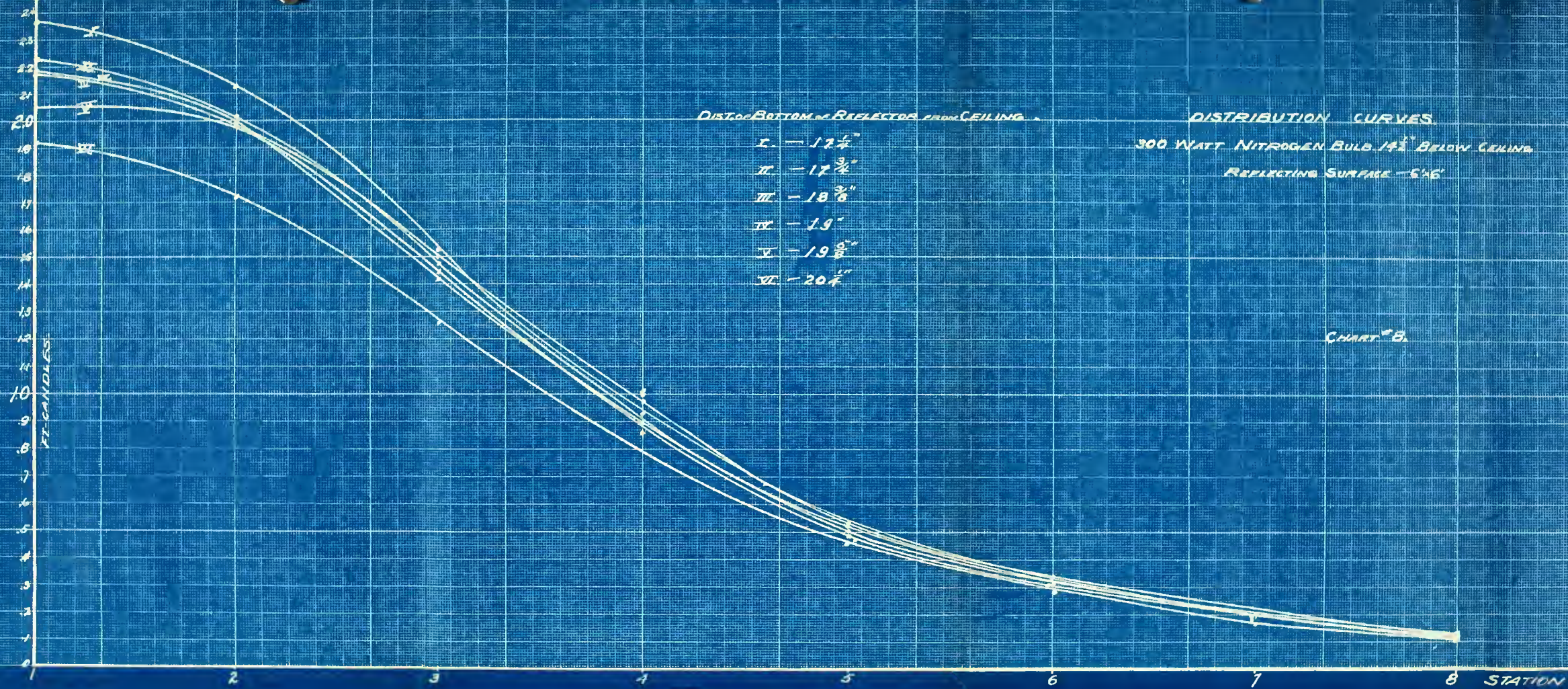
DISTRIBUTION CURVES

300 WATT NITROGEN BULB 20 1/2" BELOW CEILING

REFLECTING SURFACE - DIAM. - 4'3"

CHART #1a

STATION
Millimeters



21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

DIST. OF BOTTOM OF REFLECTOR FROM CEILING

- I - 17 $\frac{1}{4}$ "
- II - 17 $\frac{3}{4}$ "
- III - 18 $\frac{5}{8}$ "
- IV - 19"
- V - 19 $\frac{3}{4}$ "
- VI - 20 $\frac{1}{4}$ "

DISTRIBUTION CURVES

300 WATT NITROGEN BULB. 14 $\frac{1}{2}$ " BELOW CEILING.
REFLECTING SURFACE - DIAM. = 13"

CHART # 14

Profile PAPER.
Millimeters

STATION #

FT. CANDLES

